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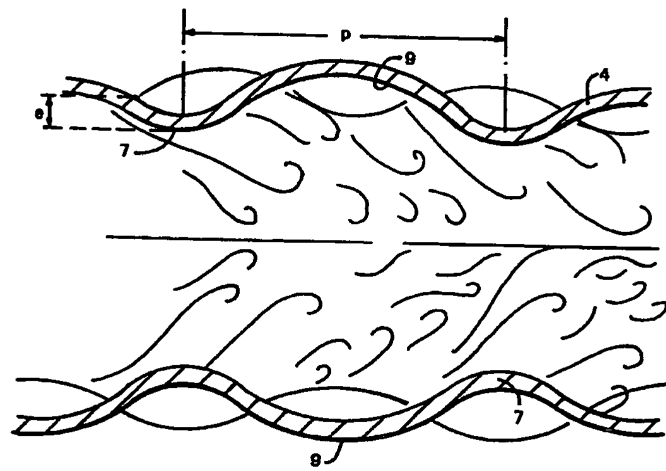

(57) Abstract

A heat exchanger includes at least one passageway (9) for the passage of at least one of the exchange media. The interior of the passageway includes at least one wall portion (4) having a plurality of projections (7) thereon which project into the passageway, and which are dimensioned and distributed so as to induce eddies in the medium, while still allowing a laminar flow of the medium through the passageway.

* See back of page

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HEAT EXCHANGERS

The invention relates to heat exchangers.

It is one object of this invention to provide a heat exchanger of high efficiency and which may be compact.

According to a first aspect of the invention there is provided a heat exchanger for the exchange of heat between two media, the heat exchanger comprising at least one passageway for the flow of one of the media, the interior of the passageway includes at least one wall portion including a plurality of projections thereon which project into the passageway, and which are distributed and dimensioned so as to induce eddies in the media while still allowing a laminar flow of the medium through the passageway.

The projections are preferably formed in the wall portion by embossing or by removal of intervening material as by etching. The wall portion may be of metal, e.g aluminium, stainless steel

or like sheet.

If the projections are too short or too far apart relative to the dimensions of the passageway then only a thin layer of medium adjacent the wall portion will be broken up, and no eddies will be induced further away from the wall so that a large portion of the medium will flow straight through the passageway without heat being transferred. On the other hand if the projections project too far into the passageway the flow will be restricted thereby to such an extent that more pumping power will be required and the overall efficiency will fall. Preferably the dimension of the projections are determined by a ratio of Dh/e within the range of between 2 and 33 and even more preferably within the range of between 5 and 12, where e is the mean height of the projections and Dh is the so-called hydraulic diameter which is defined e.g on Page 289 of the 4th edition of "Heat Transfer" by Alan J Chapman as four times the cross-sectional area divided by the wetted perimeter of the passageway. For a rectangular passageway of transverse dimensions a,b, this is equal to $\frac{2ab}{a + b}$

The distribution of the projections on the surface area of the wall portion is defined by the ratio of P/e, where P is average distance apart of the projections, and is preferably between about 4 and 22, and most preferably less than 8.

The invention may be seen to particularly advantageous effect when the two exchange media are gases, e.g air, because the specific heat capacity of gases is low.

The invention may be advantageously applied to a wide variety of types of heat exchangers including:

- plate type heat exchangers
- fin and tube type heat exchangers
- thermal wheels
- shell and tube type heat exchangers
- run round coil systems
- recuperators
- regenerators
- heat pipes
- heat pumps

In one aspect of the invention the heat exchanger may be of the plate type comprising a plurality of generally parallel rigid plates, spacing means to space the plates apart and to divide the space between each adjacent pair of plates into a plurality of parallel through passageways, the plates including wall portions as defined.

Preferably the spacing means are a plurality of parallel spaced

apart ridges which are stamped or otherwise formed into each plate. Each pair of adjacent plates are preferably arranged so that the respective sets of ridges are at an angle to each other, most preferably at right angles, so that alternate sets of parallel passageways carry alternately one of the gases at right angles to the other.

In another aspect the heat exchanger may be of the fin and tube type heat exchanger comprising a bundle of parallel tubes extending through aligned holes in a plurality of parallel spaced apart plates, the plates including wall portions as defined. The tubes may also have wall portions as defined.

In yet another aspect the heat exchanger may be of the thermal wheel type comprising a cylindrical rotatable drum, a plurality of longitudinal through passageways, a fixed barrier wall extending longitudinally towards each end face of the drum, whereby in use a medium at one temperature is passed through the passageways from one side of the barrier wall and another medium at another temperature is passed through the passageways from the other side of the barrier wall so that as the drum is rotated heat is temporarily stored within the drum and then transferred from one medium to the other, the passageways including wall portions as defined.

In order that the invention may be better understood various embodiments thereof will now be described by way of example with reference to the accompanying diagrammatic drawings, in which:

Figure 1 shows a perspective view of a plate type heat exchanger;

Figure 2 is an enlarged perspective partial view of two of the plates of the heat exchanger of Figure 1;

Figure 3 shows schematically an enlarged longitudinal sectional view of a passageway of a heat exchanger of the invention;

Figure 4 is a perspective view from above of an example of another shape of surface;

Figure 5 is a perspective partial view of a fin and tube type heat exchanger;

Figure 6 is a perspective view of a thermal wheel type heat exchanger;

Figure 7 is a schematic perspective view of two types of tube and shell type heat exchangers; and

Figure 8 is a graph showing the comparison in performance between

two plate type heat exchangers of similar size, one of which includes passageway projections according to the invention

As shown in Figure 1 a plate type heat exchanger or recuperator 1 for installation, e.g within the ventilation system of a building is generally cube shaped and is arranged so that air at an elevated temperature, e.g waste air from within the building impinges on face 2. Ambient air is drawn from the outside to impinge on a face 3 of the exchanger at right angles to face 2. Heat from the waste air is transferred to the ambient incoming air which is then passed to the interior of the building.

The heat exchanger 1 comprises a stack of plates 4 comprising square sheets of aluminium or the like. As best seen in Figure 2 each plate 4 includes a plurality of parallel spaced apart ridges 5 stamped or otherwise formed into the plate 4 with an upturned flange 6 on two opposing sides of the plate 4; only one such flange 6 is shown in Figure 2. The plate is formed with a continuous irregular pattern of teat-like projections or small embossments 7 with troughs 8 inbetween, as will be explained later. The heat exchanger is made by stacking one plate 4 above the other in such a way that the ridges 5 on each adjacent pair of plates 4 are orthogonal, although they may be arranged at any suitable angle.

The edges of the flanges 6 and the tops of the ridges 5 may be secured to the adjacent plate 4, e.g by adhesive, soldering or the like, or they may be received as a mechanical fit within an external framework (not shown).

The heat exchanger defines two sets of separate orthogonal elongate passageways 9, each set extending from one orthogonal face 2, 3 towards the opposing face so that the two air streams flow at right angles as shown by the arrows in Figures 1 and 2.

In another embodiment (not shown) the sheets may be spaced apart by other spacing means, e.g a separate corrugated spacer and defining passageways 9 between adjacent corrugations.

We have discovered that by providing the interior of the flow passageways 9 with small teat - like projections or embossments 7, it is possible to increase the performance from such a heat exchanger by a surprising degree, as compared to the smooth plates which are present in the known plate type exchangers. The small embossments 7 may be arranged in an irregular or random distribution, as shown, or in a regular pattern, not shown.

As best seen in Figure 3 the pattern is continuous and comprises small embossments 7 with troughs 8 inbetween. The medium is shown flowing from left to right. The projections 7 induce

eddies in the adjacent or boundary layer of the medium, which causes a vortex in the peripheral portion of the gas, which brings the medium into repeated contact with the wall so improving the transfer of heat through the wall from one medium to the other. As explained, the projections and the relative dimensions of the passageway are selected to control the shape and size of the eddies. The troughs 8 are important because any condensate formed from cooled moist gas adjacent to the wall surface will collect in the troughs 8 and so will not hinder further heat transfer. This is in contrast to a plate in which no such troughs are present and a film of condensate forms, e.g on a flat surface between the ridges and forms a barrier to further heat transfer.

The particular shape of the projections may vary. As an example figure 4 shows a perspective view from above of a surface according to the invention, which is especially efficient. The media is shown flowing in the direction of the arrow. The projections have a frontal portion 20 which is of a shape similar to the leading portion of a tear-drop so as to reduce the resistance to flow, and the rear most portion defines two side by side vertical concave surfaces 21, which are shaped so as to maximize vortex shredding and the extent of the eddies as the media flows over the projections, while ensuring minimal frictional losses.

The pattern may be formed by embossment, eg by passing a flat sheet between rollers having projections thereon, removal of intervening material as by etching, addition of material to form the projections or by moulding as in a sintered surface.

We have found that a ratio of Dh/e of between 2 and 33 and most preferably of between 5 and 12 where e is the average height of the projections and Dh is the so-called hydraulic diameter, gives good results. The optimum conditions are achieved when eddies are induced across substantially the whole volume of the passageway while the flow is still laminar, that is to say Reynolds number is less than about 2000, or in other words the laminar flow layer closest to the longitudinal axis of the passageway is as thin as possible, without the flow becoming turbulent. A ratio of D^h/e of 2-or-so will only be of use when there is excess energy to be dissipated, and where pressure and frictional losses in the heat exchanger are unimportant. An example of such a case might be a gas turbine in a power station. A $D^h/_e$ of 33 will still induce eddies as described, but to a less marked degree and might be useful where the reduction of pressure loss is especially important.

A useful working range has been found to be between about 5 and 12 for the majority of cases where a compromise is required

between compactness of the heat exchanger on the one hand, and low pressure drop or pumping requirement on the other. Factors which affect the choice include whether the media are liquid or gaseous, their viscosity, the flow rate and Reynolds number, amongst others.

The spacing apart or pitch P of the projections is selected, compared to the height of the projections, to be comparable to the distance over which an eddy induced by passage over a projection has substantially damped down, but not so widely spaced that regions of straight line or laminar flow are present between the projections and not so closely packed that substantially no eddies are formed. We have found that a ratio of P/e of between about 4 and 22 to be an outside range which, for the majority of cases, will satisfy these conditions, with a more representative range of between 4 and 8 for the majority of cases. As before, the factors affecting the choice include the nature of the media, flow rate, amongst others.

Other embodiments of the invention are shown in Figures 5, 6 and 7. Figure 5 shows a so-called fin and tube type heat exchanger in which a bundle of parallel spaced tubes 10 is supported in aligned holes which are present in spaced apart plates 11. One medium is caused to flow through the tubes 10, while the other medium is caused to flow through the passageway defined by the

space between the plates 11. As shown, the spacing has been exaggerated for clarity. According to the invention the plates 11 and also the tubes 10 may include the small embossments 7.

Figure 6 shows a thermal wheel type heat exchanger comprising a cylindrical rotatable drum 12 driven by a drive belt 13 and motor 14. A spiral coil of aluminium or like sheet 15 is received co-axially within the drum 12 and the spirals are spaced apart by a continuous length of corrugated spacer 16. Passageways 17 are defined between adjacent corrugations for the flow of the two media. When the exchanger is used in a ventilation system the two streams may be waste air and incoming ambient air. Two barrier walls 18 are fixed relative to the drum 12 and extend towards the centre of each end face of the drum to separate the two streams of air, one of which flows from one side of one wall 18 through the rotating drum 12 to emerge on the other side, while the other stream of air is caused to flow in the opposite direction from the opposite side of the respective wall 18, as shown by the arrows. Energy from one of the air streams is temporarily stored within the walls of the passageways 17 and transferred to the other air stream as the drum rotates. According to the invention the spiral coil 15 and the corrugated spacer 16 are formed from embossed sheet having projections 7.

Two types of shell and tube type heat exchanger are shown

schematically in figures 7a and 7b. The heat exchanger of figure 7a comprises a plurality of concentric spaced tubes 22 and the two media are arranged to flow along alternative passageways 23 defined by the annular spaces between the tubes 22 as shown the by the arrows. According to the invention the tubes 22 include projections 7 which project into the passageway 23.

The heat exchanger of Figure 7b comprises a bundle of parallel tubes 24 which are recieved within an outermost tube 25. Flow diversion plates 26 may also be present within the outermost tube 25. The two media are arranged to flow through the bundle of tubes 24 and through the outermost tube 25. According to the invention the inner surface of the outer tube 25, the bundle of tubes 24 and the diversion plates 26 may include projections 7 according to the invention.

In an experiment two plate-type heat exchangers were constructed. One included passageways made from smooth aluminium sheet. The other exchanger was constructed using the same number and size of plates, but was made from an aluminium sheet known as "Stucco" (trade name) manufactured by Alcan Limited and having an irregular pattern of small-teat like embossments. The Stucco sheeting used had a mean embossment height e of 0.32 mm and a mean pitch P of 3.5 mm. The embossed exchanger was constructed so that the ratio of Dh/e was equal to 7.5, while the other

exchanger had passageways of similar dimension. A comparison of the heat transfer from the two exchangers is shown in the graph of Figure 8. The y-axis represents the heat transfer per unit temperature difference and per unit heat exchanger volume in Watts per Kelvin per cubic metre. The x axis represents the friction power expenditure per unit core volume in Watts per cubic metre. The heat exchanger made using the embossed plate transferred 20.24 W $m^{-3}k^{-1}$ compared to the known exchanger which transferred 8.67 W $m^{-3}k^{-1}$. In other words, for a given power loss, a heat exchanger according to the invention had an efficiency gain of about 57% over the known exchanger. A heat exchanger according to the invention could therefore have a volume which is 57% less in order to achieve the same performance, or in the alternative would require 57% less pumping power to pump the air through the exchanger to achieve a similar performance. Similar increases in performance could be expected for any other gas to gas heat exchanger, such as the thermal wheel type, the fin and tube type and the shell and tube types described above.

The fins and louvres present on many type of heat exchangers may additionally be formed in wall portions of the invention to achieve useful increases in performance. The use of embossed sheet may give such large increases in performance that additional fins and louvres are not required, thereby leading to

large reductions in manufacturing costs.

The invention is not limited to the embodiments shown, for example the projections may be formed in a variety of materials eg glass or ceramic, or may be formed from a sintered material.

CLAIMS

1. A heat exchanger for the exchange of heat between two media, the heat exchanger comprising at least one passageway for the flow of one of the media, the interior of the passageway including at least one wall portion having a plurality of projections thereon which project into the passageway and which are dimensioned and distributed so as to induce eddies in the medium while still allowing a laminar flow of the medium through the passageway.

2. A heat exchanger according to Claim 1 characterised in that the projections are formed in the wall portion by embossing.

3. A heat exchanger according to Claim 1 or Claim 2 characterised in that the ratio Dh/e lies within the range of between about 2 and about 33, where Dh is the hydraulic diameter of the passageway and e is the average height of the projections.

4. A heat exchanger according to any of Claims 1 to 3, characterised in that the ratio P/e lies within the range of between about 4 and about 22, where P is the average distance apart of the projections.

5. A heat exchanger according to any preceding Claim characterised in that at least one of the exchange media are gaseous.

6. A heat exchanger according to any preceding claim characterised in that the heat exchanger is of the plate type comprising a plurality of generally parallel plates, spacing means to space the plates apart and to divide the space between each adjacent pair of plates into a plurality of parallel through passageways, the wall portions including the projections being present on the plates.

7. A heat exchanger according to any of Claims 1 to 4, characterised in that the heat exchanger is of the fin and tube type comprising a bundle of parallel tubes extending through aligned holes in a plurality of parallel spaced apart plates, the wall portions including the projections being present on the plates.

8. A heat exchanger according to any of Claims 1 to 4, characterised in that the heat exchanger is of the thermal wheel type comprising a cylindrical rotatable drum, a plurality of longitudinal through passageways extending through the drum, a fixed barrier wall extending longitudinally towards each end face of the drum, whereby in use a

medium at one temperature is passed through the passageways from one side of the barrier wall and another medium at another temperature is passed through the passageways from the other side of the barrier wall so that as the drum is rotated heat is temporarily stored within the drum and then transferred from one medium to the other, the wall portions including the projections being present on the passageway walls.

9. A heat exchanger according to any preceding Claim characterised in that each projection includes a frontal portion of a similar shape to the leading portion of a teardrop, and a rearmost portion defining at least one vertically disposed concave surface, thereby to maximise vortex shredding and the extent of the eddies as the media flows over the projection while ensuring minimal frictional losses.

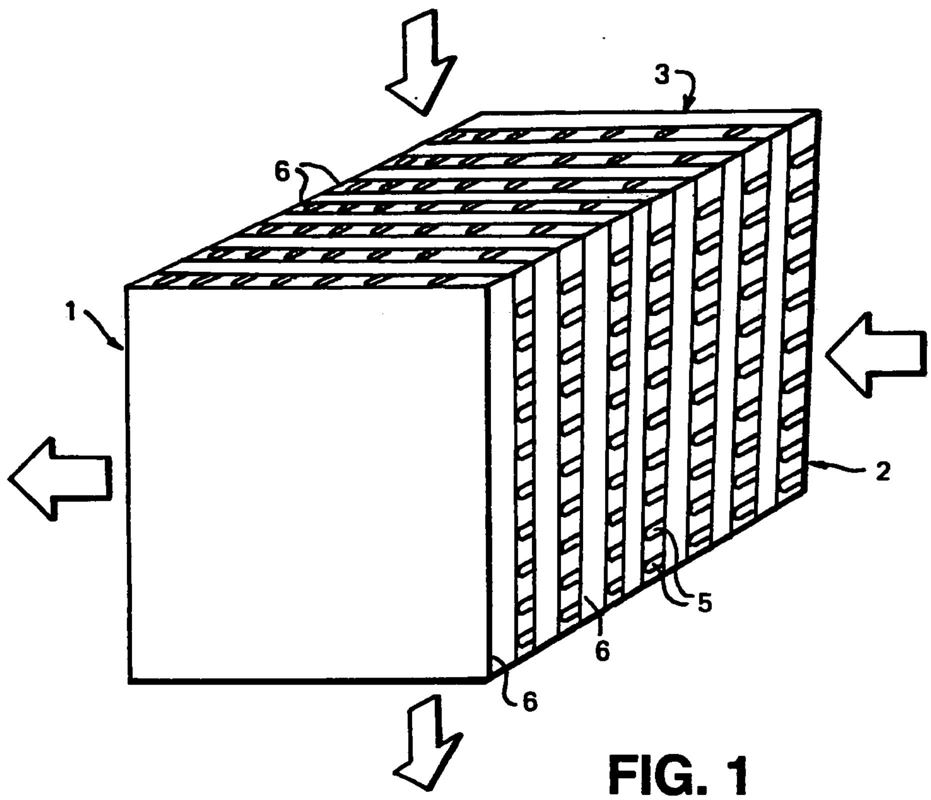

FIG. 1

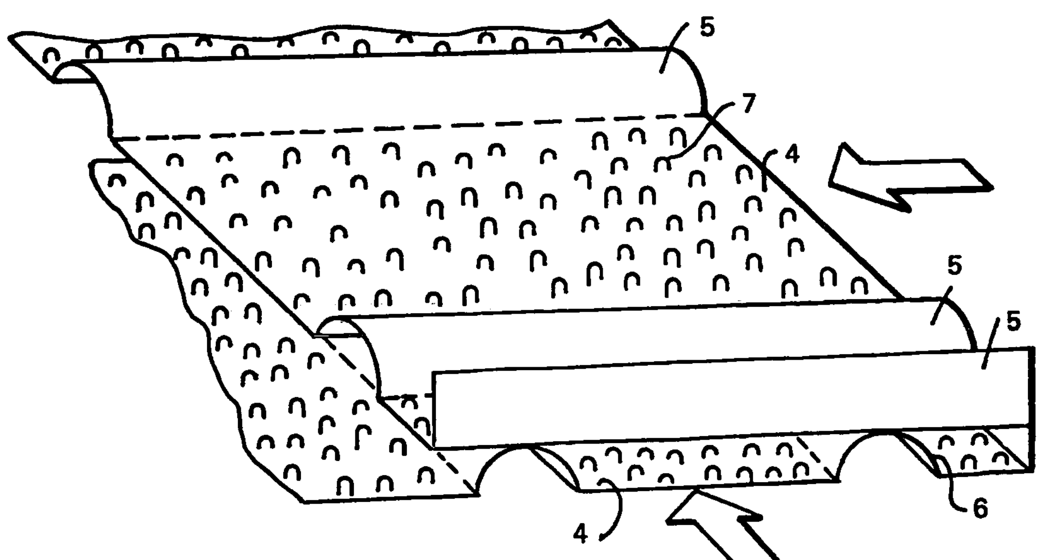

FIG. 2

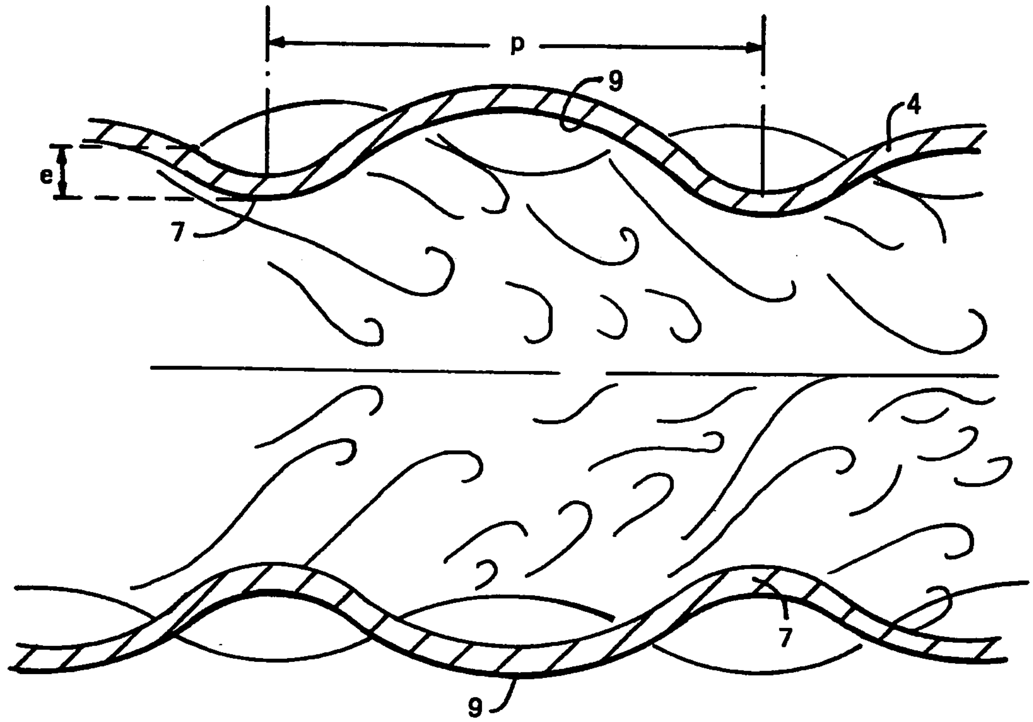

FIG. 3

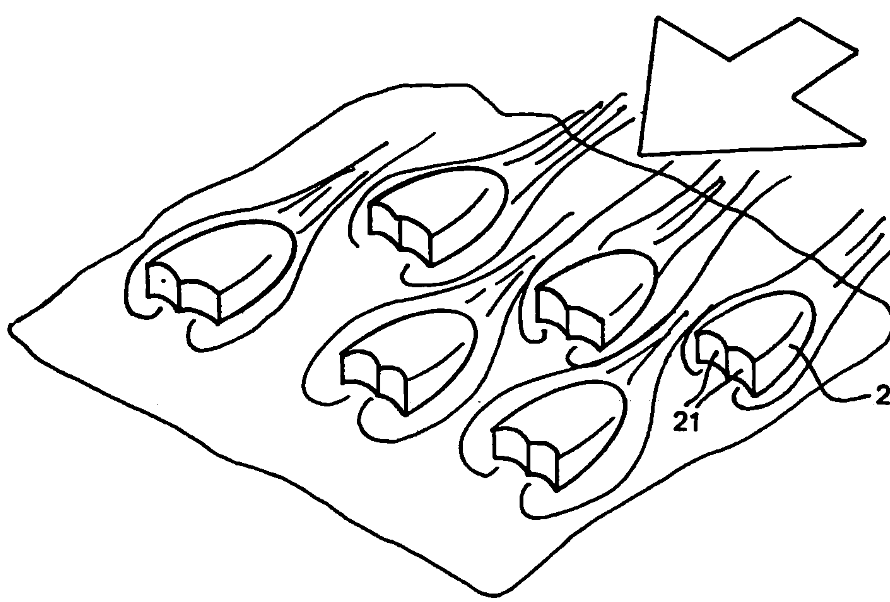

FIG. 4

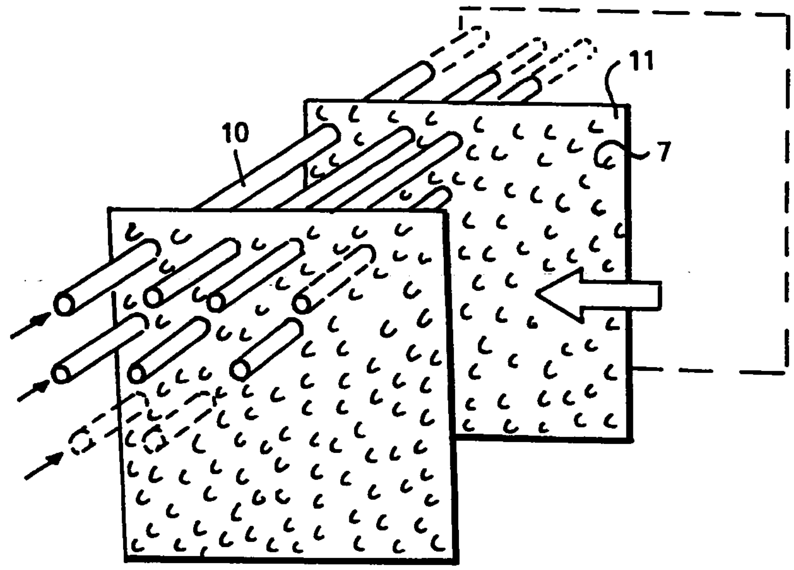

FIG. 5

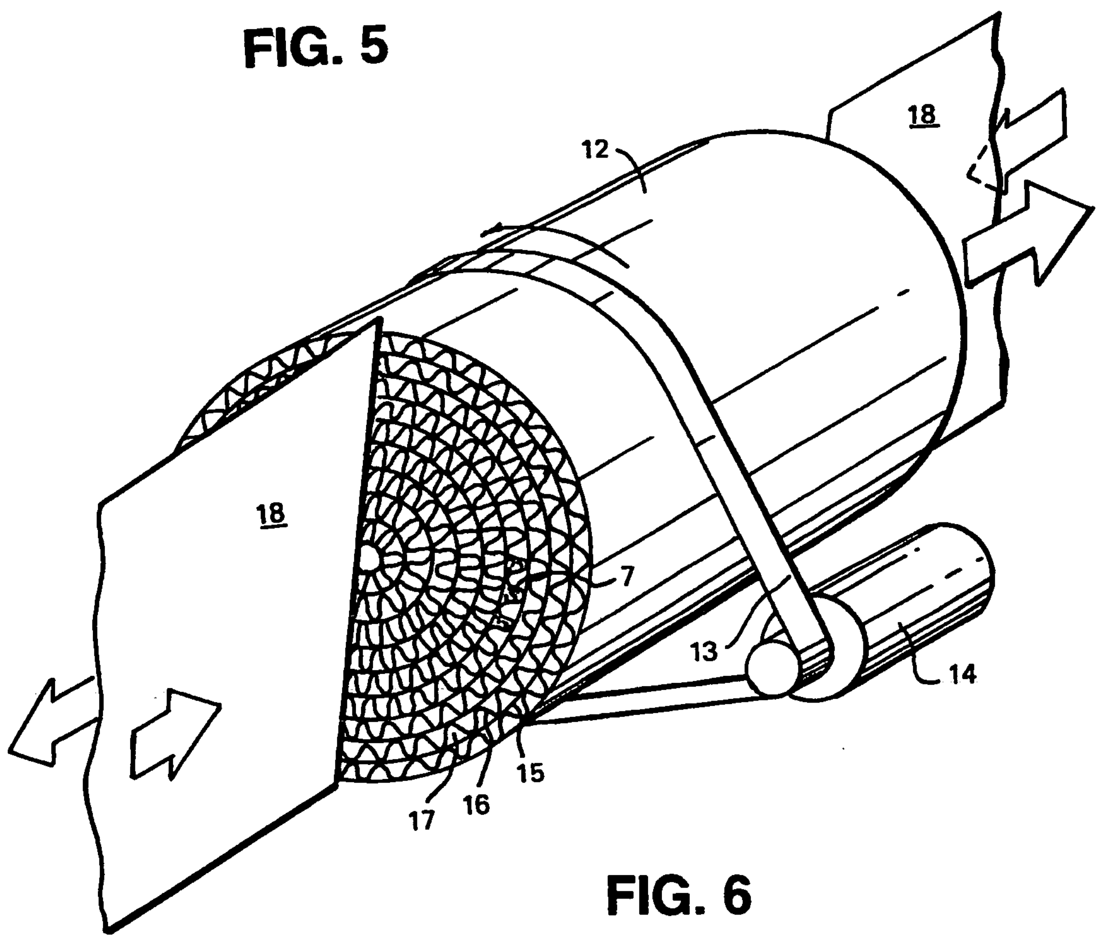

FIG. 6

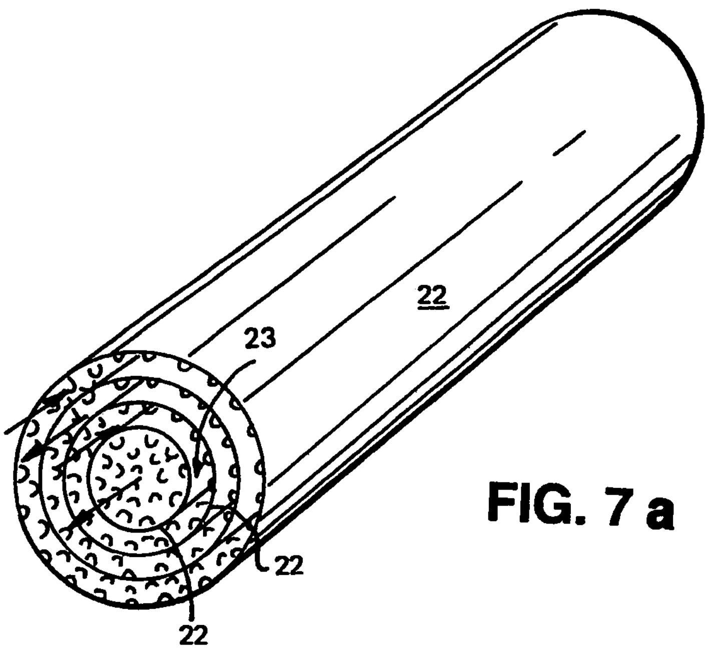

FIG. 7 a

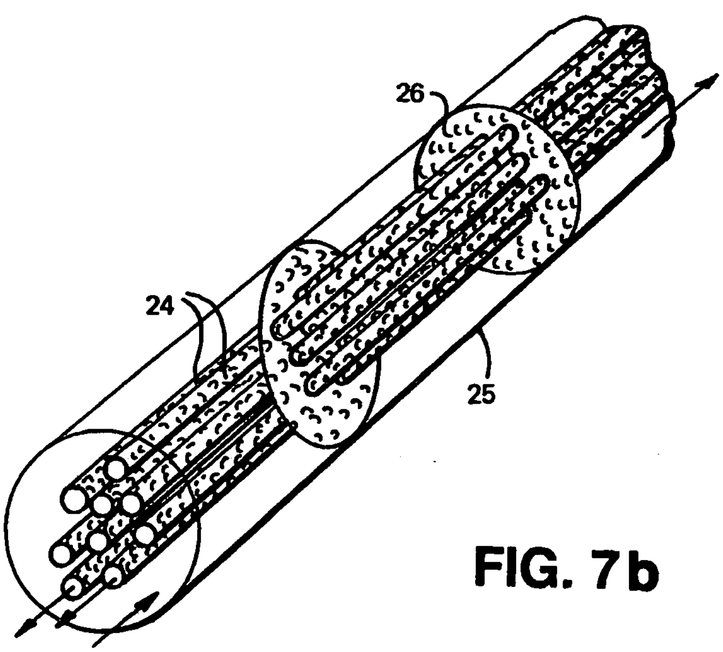

FIG. 7b

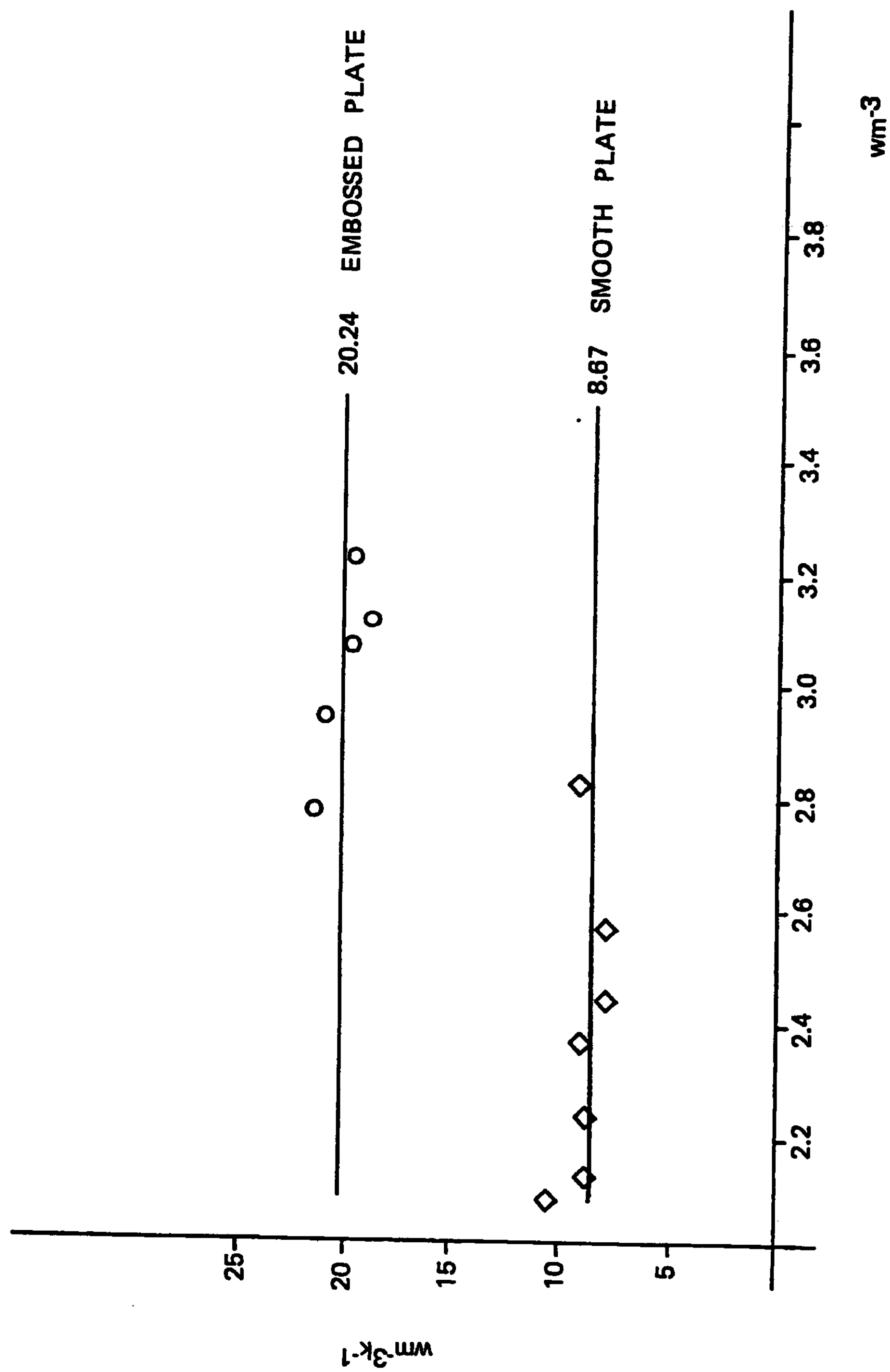
20.24 EMBOSSED PLATE
8.67 SMOOTH PLATE
wm-3
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
wm-3k-1
25
20
15
10
5

FIG. 8

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 90/01254

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^5: F 28 F 13/02

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^5	F 28 F, F 15 D

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	FR, A, 1230495 (SAUNIER DUVAL) 16 September 1960 see page 1, left-hand column, lines 12-23,36 - right-hand column, line 12; page 2, left-hand column, lines 40-44; figure 1	1,7
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X	GB, A, 894510 (ASSOCIATED ELECTRICAL IND. LTD) 26 April 1962 see page 2, line 80 - page 3, line 35; figures 1-3	1
	--	
X	BE, A, 711208 (MEURA) 1 July 1968 see page 3, line 22 - page 4, line 6; page 4, lines 22-24; figures 1,2	1,2,5,7
	--	
P,X	GB, A, 2218790 (BRITISH AEROSPACE PUBLIC CO. LTD) 22 November 1989 see page 2, line 25 - page 3, line 14; page 4, lines 1-3; figures 1,2	1
A		8
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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
16th November 1990	29. 11. 90
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	M. Peis M. PEIS

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

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A	FR, A, 2298075 (BORG-WARNER CORP) 13 August 1976 see page 6, lines 9-15; figures 9,10 --	1,2,6
A	GB, A, 340379 (ANTONI) 22 January 1931 see figures 1,2 --	1
A	US, A, 4004615 (STERN et al.) 25 January 1977 see column 3, line 34 - column 4, line 5; figure 3 --	1,9
A	DE, A, 2156579 (KAUDER) 24 May 1973 see claims 1,2; figure --	1,3,4
A	US, A, 4232728 (FENNER et al.) 11 November 1980 see figures 2,4,5,12 ----	1,3,4

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. GB 9001254

SA 39672

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 23/11/90
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